

## Preparation to the CMB Planck analysis : contamination due to the polarized galactic emission

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The Planck satellite experiment, which was launched the 14th of may 2009, will give an accurate measurement of the anisotropies of the Cosmic Microwave Background (CMB) in temperature and polarization. This measurement is polluted by the presence of diffuse galactic polarized foreground emissions. In order to obtain the level of accuracy required for the Planck mission it is necessary to deal with these foregrounds. In order to do this, we have developed and implemented coherent 3D models of the two main galactic polarized emissions : the synchrotron and thermal dust emissions. We have optimized these models by comparing them to preexisting data : the K-band of the WMAP data, the ARCHEOPS data at 353 GHz and the 408 MHz all-sky continuum survey. By extrapolation of these models at the frequencies where the CMB is dominant, we are able to estimate the contamination to the CMB Planck signal due to these polarized galactic emissions.

### 1 Introduction

The PLANCK satellite<sup>2</sup> which is currently in flight and acquiring data, should give the most accurate measurement of the anisotropies of the CMB in temperature and polarization with a sensitivity of  $\Delta T/T \sim 2 \times 10^{-6}$  and an angular resolution of 5 arcmin. Thanks to its range of frequencies between 30 and 857 GHz it will give a great amount of information about galactic and extra-galactic emissions. In order to obtain the level of accuracy required for the Planck mission it is necessary to deal with these foregrounds and the residual contamination due to these foreground emissions. While, for the full sky, these emissions have the same order of magnitude than the CMB in temperature, they dominate by a factor 10 in polarization<sup>2</sup>. The principal polarized Galactic microwave emissions come from 2 effects: thermal dust emission and synchrotron emission. The synchrotron is well constrained by the 408 MHz all-sky continuum survey<sup>8</sup>, by Leiden [Leiden/DRAO] between 408 MHz and 1.4 GHz<sup>17</sup>, by Parkes at 2.4 GHz<sup>5</sup>, by the MGLS *Medium Galactic Latitude Survey* at 1.4 GHz<sup>16</sup> and by the satellite WMAP *Wilkinson Microwave Anisotropies Probe* (see e.g.<sup>9</sup>). The synchrotron emission is due to ultrarelativistic electrons spiraling in the large-scale galactic magnetic field. The thermal dust emission which has already been constrained by IRAS<sup>14</sup> and COBE-FIRAS<sup>3</sup> is due to dust grains heated by the interstellar radiation field. Those grains emit a polarized submillimetric thermal radiation<sup>3</sup> as observed by e.g. ARCHEOPS<sup>1</sup>. The polarization of these two types of radiation is orthogonal to the field lines. We developed models of those emissions using the 3D galactic distribution of the magnetic field and the matter density. The models are constrained using pre-existing data and used to estimate the residual contamination to the CMB Planck signal

due to these polarized galactic emissions.

## 2 3D modelling of the Galaxy

A linearly polarized emission<sup>11</sup> at a given frequency  $\nu$  in GHz, can be described by the Stokes parameters I, Q and U. For the polarized foreground emissions integrated along the line of sight we obtain, for synchrotron:

$$I_s = I_{\text{Has}} \left( \frac{\nu}{0.408} \right)^{\beta_s}, \quad (1)$$

$$Q_s = I_{\text{Has}} \left( \frac{\nu}{0.408} \right)^{\beta_s} \frac{\int \cos(2\gamma) p_s n_e (B_l^2 + B_t^2)}{\int n_e (B_l^2 + B_t^2)}, \quad (2)$$

$$U_s = I_{\text{Has}} \left( \frac{\nu}{353} \right)^{\beta_s} \frac{\int \sin(2\gamma) p_s n_e (B_l^2 + B_t^2)}{\int n_e (B_l^2 + B_t^2)}, \quad (3)$$

where  $B_n$ ,  $B_l$  and  $B_t$  are the magnetic field components along, longitudinal and transverse to the ligne of sight. The polarization fraction  $p_s$  is set to 75%.  $I_{\text{Has}}$  is the template map<sup>8</sup>. The maps are extrapolated at all the Planck frequencies using the spectral index  $\beta_s$  which is a free parameter of the model.

For the thermal dust emission the Stokes parameters are given by:

$$I_d = I_{sfd} \left( \frac{\nu}{353} \right)^{\beta_d}, \quad (4)$$

$$Q_d = I_{sfd} \left( \frac{\nu}{353} \right)^{\beta_d} \int n_d \frac{\cos(2\gamma) \sin^2(\alpha) f_{\text{norm}} p_d}{n_d}, \quad (5)$$

$$U_d = I_{sfd} \left( \frac{\nu}{353} \right)^{\beta_d} \int n_d \frac{\sin(2\gamma) \sin^2(\alpha) f_{\text{norm}} p_d}{\int n_d}, \quad (6)$$

where the polarization fraction  $p_d$  is set to 10 %,  $\beta_d$  is the spectral index (set to 2.0) and  $f_{\text{norm}}$  is an empirical factor, fitted to the ARCHEOPS data. The  $I_{sfd}$  map is the model 8 of Schlegel *et al.*<sup>14</sup>.

The models are based on an exponential distribution of relativistic electrons on the Galactic disk, following<sup>4</sup>, where the radial scale  $h_r$  is a free parameter. The distribution of dust grains  $n_d$  is also exponential<sup>1</sup>. The Galactic magnetic field is composed a regular and a turbulent components. The regular component is based on the WMAP team model<sup>13</sup> which is close to a logarithmic spiral to reproduce the shape of the spiral arms<sup>7</sup>. The pitch angle  $p$  between two spiral arms is a free parameter of the model. The turbulent component is described by a Kolmogorov's law<sup>7</sup> spectrum with a relative amplitude  $A_{\text{turb}}$ .

## 3 Comparison to data

We computed Galactic profiles in temperature and polarization for various bands in longitude and latitude and various values of the free parameters. In order to optimize these 3D models we compare them to Galactic profiles computed with preexisting data using a  $\chi^2$  test. For the synchrotron emission in temperature, we use the 408 MHz all-sky continuum survey<sup>8</sup> as shown on Figure 1. In polarization we use the K-band WMAP 5 years data. The thermal dust emission model is optimized using the polarized ARCHEOPS data<sup>1</sup> at 353 GHz.

The best fit parameters for the 3D model in polarization are given in Table 1. The results are consistent for the three sets of data. In particular we obtain compatible results for the

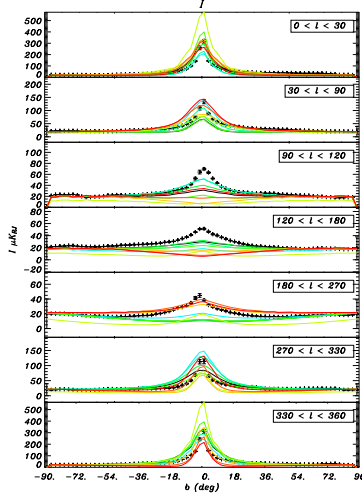


Figure 1: Galactic profiles in temperature at 408 MHz Haslam data in black and our synchrotron emission model for various values of the pitch angle  $p$  (from green to red).

synchrotron and thermal dust emission models.  $A_{turb}$  and  $h_r$  are poorly constrained as was already the case in Sun *et al*<sup>15</sup>. The best fit value of the pitch angle  $p$  is compatible with results obtained by other studies<sup>15,13</sup>. The best fit value for the spectral index of the synchrotron emission is lower than the value found by<sup>15,13</sup>, but this is probably due to the choice of normalisation for the regular component of the magnetic field. With these models we reproduce the global structure of the data (see for instance the Figure 1) apart from the Galactic Center.

Table 1: Best fit parameters for synchrotron and thermal dust emission models.

	$p(deg)$	$A_{turb}$	$h_r$	$\beta_s$	$\chi^2_{min}$
<i>WMAP</i>	$-30.0^{+40.0}_{-30.0}$	$< 1.25$ (95.4 % CL)	$> 1$ (95.4 % CL)	$-3.4^{+0.1}_{-0.8}$	5.72
<i>HASLAM</i>	$-10.0^{+70.0}_{-60.0}$	$< 1.25$ (95.4 % CL)	$5.0^{+15.0}_{-2.0}$	$\emptyset$	5.81
<i>ARCHEOPS</i>	$-20^{+80}_{-50}$	$< 2.25(95.4\%CL)$	$\emptyset$	$\emptyset$	1.98

## 4 Conclusions

From the above best fit parameters we estimated the contamination of the CMB PLANCK data by the polarized galactic emissions. We compared power spectra computed with simulations of the CMB PLANCK data<sup>a</sup>. Figure 2 shows the temperature and polarization power spectra at 143 GHz for the CMB simulation (*red*) and the Galactic foreground emissions, obtained by applying a Galactic cut  $|b| < 15^\circ$  (*black*). The foreground contamination seems to be weak but for the B modes an accurate foreground subtraction is extremely important concerning the detection of the primordial gravitational waves. More details can be found in<sup>6</sup>.

## References

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<sup>a</sup>We used cosmological parameters for the  $\Lambda$ CDM-like model proposed in<sup>10</sup> with a tensor to scalar ratio of 0.03.

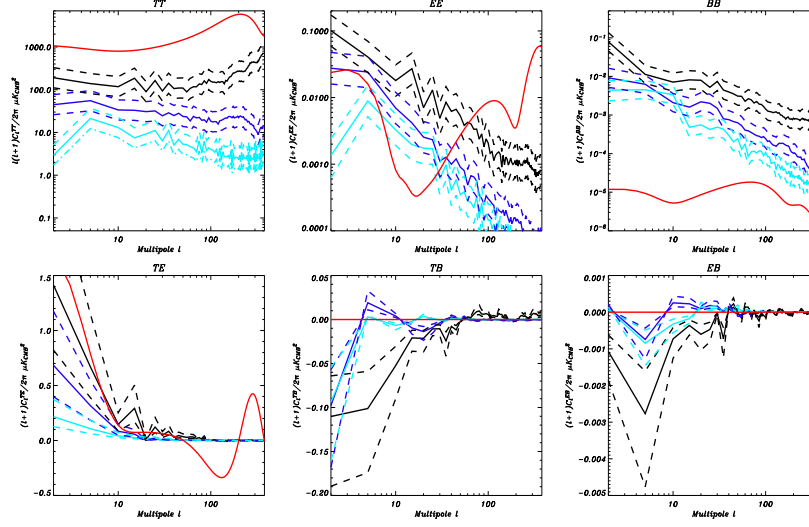


Figure 2: Clockwise from top left : power spectra  $C_l^{TT}, C_l^{EE}, C_l^{BB}, C_l^{TE}, C_l^{TB}, C_l^{EB}$  at 143 GHz applying a galactic cut of  $|b| < 15^\circ$  (black),  $|b| < 30^\circ$  (blue) and  $|b| < 40^\circ$  (cyan) (see text for details).

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